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A PEST OF CURED TOBACCO, EPHESTIA ELUTELLA HÜBNER

By W. D. Reed, *Associate Entomologist*, and Erskine Livingstone and A. W. Morrill, jr., *Junior Entomologists, Division of Stored Product Insects, Bureau of Entomology*

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INTRODUCTION

The phycitid moth *Ephestia elutella* Hbn. has appeared in the bright-tobacco belt of the United States as a pest of flue-cured tobacco. The infestation was discovered on August 8, 1930, as reported by Back and Reed (*1*).[1] Up to that time the cigarette beetle (*Lasioderma serricorne* Fab.) has been regarded by the tobacco industry as the most destructive pest of cured tobacco. The appearance of the new pest and the possibility of its further spread have aroused the industry, and many inquiries concerning the insect have been received from tobacco dealers. The larvae of *Ephestia elutella* attack the brighter grades of flue-cured tobacco, eating much of the leaf between the veins and otherwise marring the appearance of tobacco in hogsheads and cases. The mere presence of the insect may cause the tobacco to depreciate in value. The work of larvae on leaves of flue-cured tobacco is shown in Figure 1. Jack (*6, p. 32*), in writing of the importance of *E. elutella* as a pest of cured tobacco in Southern Rhodesia, said:

> Tobacco manufacturers in Britain take a very serious view of infestation with this insect, and infested bales of tobacco are depreciated in value far beyond the value of the leaf actually destroyed or damaged. Consequently this pest is to be regarded as a menace of the first importance.

Observations on the moth in tobacco warehouses have been made at frequent intervals since its discovery there. On June 22, 1931, life-history studies were undertaken in the laboratory at Richmond, Va. The purpose of this circular is to make available for the tobacco industry the results of these studies as far as they have progressed.

[1] Italic numbers in parenthesis refer to Literature Cited, p. 16

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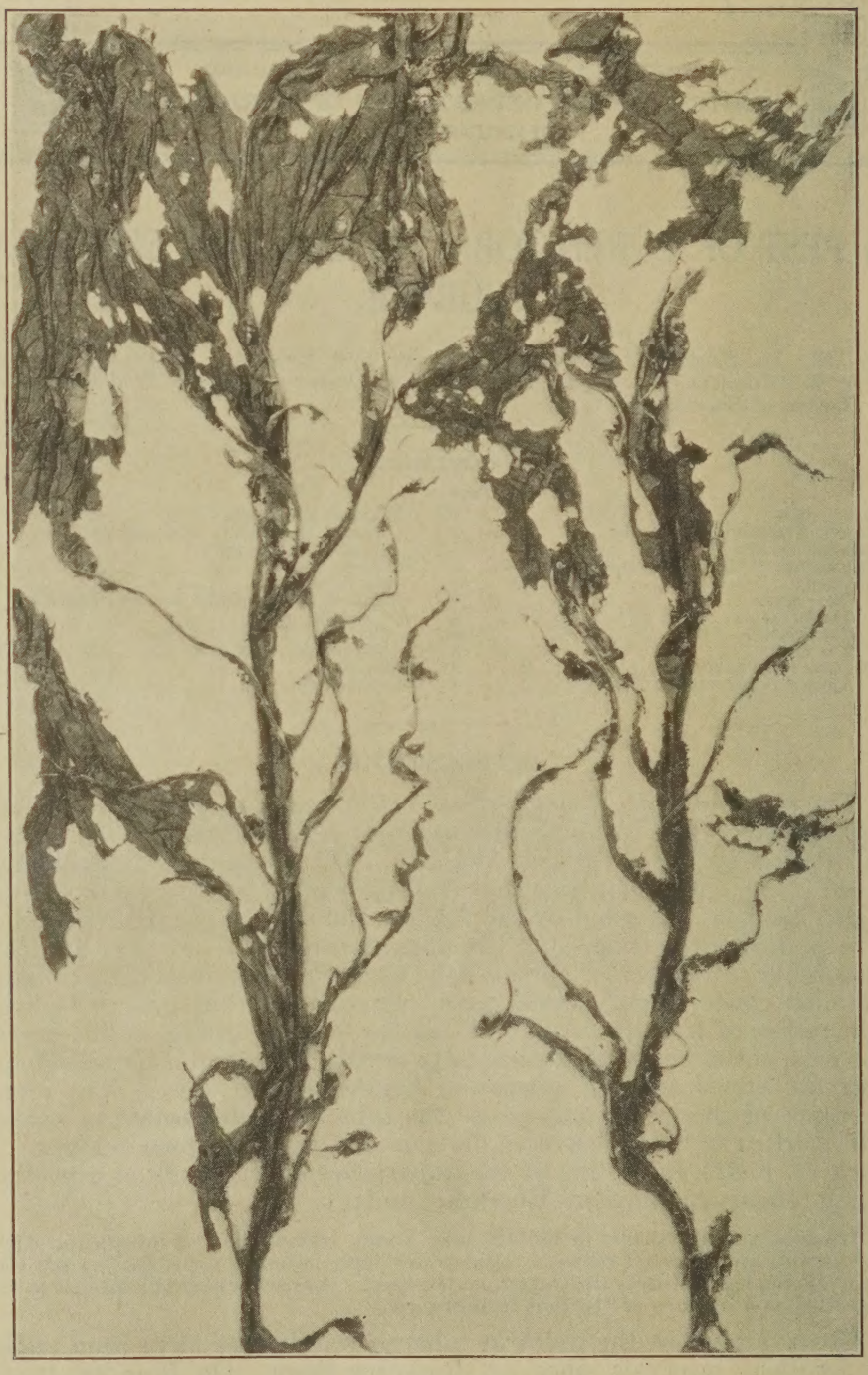

FIGURE 1.—Individual tobacco leaves illustrating the work of larvae of *Ephestia elutella* in cured tobacco. Excrement of the larvae may be seen attached to the webbing along the larger veins of the leaves

RECORDS OF INFESTATION IN TOBACCO

Ephestia elutella was recorded as a pest of cured tobacco in Russia in 1915 (*9, p. 7*). In a weekly circular issued by the tobacco section of the Bureau of Foreign and Domestic Commerce [2] September 9, 1930, attention was called to the appearance of the larvae of *E. elutella* in stocks of tobacco held in bond in one of the London warehouses, where it was feared that the work of the larvae would cause the value of the tobacco to depreciate materially. This London infestation occurred in tobacco imported from Rhodesia, Africa.

Mokrzecki (*8*) published in 1931 a bulletin in Polish on the life history and control of *Ephestia elutella* in the tobacco warehouses of Poland. The following information regarding the occurrence of this insect is quoted from the German résumé of this paper as translated for the present writers:

> The author has inspected the damage done by the larvae of *Ephestia elutella* in Simferopol and Yalta (Crimea) during the years 1909–1917 and described its biology in general terms. He furthermore had this pest under observation in the storage buildings in Sukhum (Caucasus, 1911) and in storage at Philippopol (Bulgaria), 1921. * * *
>
> The larva has been imported into Poland with bales of tobacco leaves purchased in Bulgaria and Greece, and *Ephestia elutella* is found at the present in the tobacco storage houses of Poland.
>
> The author had an opportunity in 1929 and 1930 to inspect about 20 tobacco factories and storehouses in Poland, and to convince himself that the main infestations of tobacco came from Bulgaria and to a lesser extent from Greece and other countries, and that these importations were more or less infested with larvae of *Ephestia elutella.*

Bovingdon (*2*) recorded in the August 1, 1931, issue of the British trade journal Tobacco the appearance of the moth *Ephestia elutella* in stores of tobacco in England, Bulgaria, Russia, and the United States.

Jack (*6*) published in January, 1932, an account of the appearance of *Ephestia elutella* in stocks of tobacco in Salisbury, Southern Rhodesia. He stated that up to that time it had not been found in Rhodesia anywhere except in Salisbury. He also stated that the moth had been found infesting tobacco in Bulgaria in 1928.

ECONOMIC HISTORY

Ephestia elutella has been recorded as attacking many dried vegetable products and has been carried in these products by commerce to all parts of the world. Réaumur (*11, p. 275–277*) in 1737 gave an account of a moth that injured chocolate, and it is conceded that he referred to *Ephestia elutella*. Chittenden (*3, p. 9*) said that the habits of the moth had been known in Europe since early in the seventeenth century but that American records showed nothing positive regarding injuries by the species. Maskew (*7*) published an account of the appearance of *E. elutella* in a shipment of walnuts imported at San Francisco, Calif., from Manchuria, and regarded it as a serious pest of walnuts. De Ong (*4*) reported: "Large shipments of peanuts infested with the currant moth, *Ephestia elutella* Hübner, were repeatedly received at the San Francisco port from China during the fall of 1924." Munro and Thomson (*10, p. 22*) reported this moth to be the most

[2] UNITED STATES DEPARTMENT OF COMMERCE, BUREAU OF FOREIGN AND DOMESTIC COMMERCE, TOBACCO DIVISION. THE TOBACCO SITUATION IN SOUTH AFRICA AND SOUTHERN RHODESIA. U. S. Dept. Com., Bur. Foreign and Dom. Com., Tobacco Div. Tobacco Markets and Conditions Abroad no. 270, p. 5–7. 1930. [Multigraphed.]

important insect affecting cacao in London. Gibson and Twinn (*5, p. 29*), writing of Canadian conditions, reported the presence of *E. elutella* in Canada. Zacher (*12, p. 47*) recorded the insect as occurring throughout the warmer parts of Europe and extending as far north as the southern part of Sweden. Reports of occurrence in the United States and Canada indicate that this insect has been widely distributed by commerce in these countries. Additional localities from which this insect has been reported are Africa, Australia, China, and many tropical countries, including Ceylon, Java, Samoa, West Indies, Brazil, Costa Rica, and Panama. However, none of these records of occurrence refer to the insect as a pest of tobacco, except those already mentioned, from Russia, Poland, Bulgaria, Greece, Africa, England, and the United States.

FIGURE 2.—Eggs of *Ephestia elutella* laid near the midrib of a leaf of flue-cured tobacco. × 25

It will be interesting to determine, if possible, whether the infestation in tobacco warehouses in this country is the result of a foreign importation of *Ephestia elutella* that normally feeds on tobacco, or whether the species in the United States, normally feeding on various stored food products, has begun to acquire a taste or preference for tobacco.

OBSERVATIONS ON STAGES OF EPHESTIA ELUTELLA ON TOBACCO

THE EGGS

The eggs of *Ephestia elutella* are elliptical and are grayish white when laid. Viewed through a binocular microscope, the shells appear to have a granular texture. They are about one-fortieth to one-fiftieth inch long, and are visible to the unaided eye on tobacco leaves. There they are laid either singly or in small clusters. A small cluster of eggs attached to a leaf of flue-cured tobacco near the midrib is shown in Figure 2. The eggs, when deposited, have soft shells which harden soon after exposure to the air. In clusters they sometimes press upon

one another and have distorted shapes when the shells harden. The grayish-white color of the eggs changes to light brown during the incubation period. The newly hatched larvae emerge from eggs through circular openings in the end, and the eggshells, retaining their original shape, often remain attached to the tobacco leaves.

THE LARVAE

The larvae on tobacco vary considerably in color; some are tinged with yellow; others are brownish, white, or pinkish. Their bodies are sparsely covered with colorless hairs. The young larva begins feeding soon after hatching, if suitable food is available. When tobacco leaves are hard and dry the young larvae have difficulty in feeding, and there is heavy mortality when they are fed on tobacco leaves that have a low moisture content. The larvae devour the tender parts of the leaf, between the veins and the midrib, and pellets of their excrement are often attached on silken threads spun by them. Full-grown larvae usually range from three-eighths to five-eighths inch in length (*10*) (fig. 3), and brown spots on the dorsal side of the body segments give them a striated appearance. They crawl rapidly when moving about among tobacco leaves or when searching for a suitable place in which to pupate.

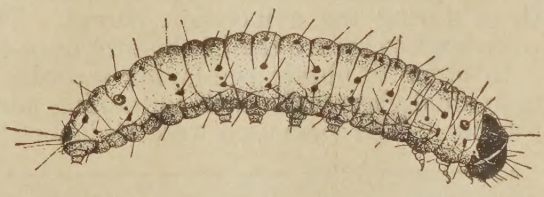

FIGURE 3.—Larva of *Ephestia elutella*, × 12 (approximately). The natural length of the larva in tobacco is about three-eighths to five-eighths inch. (Munro and Thomson)

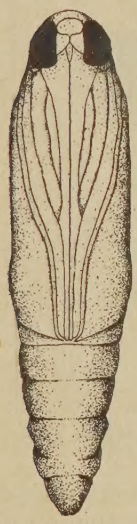

FIGURE 4.—Pupa of *Ephesita elutella*, ×12 (approximately). The pupa ranges from light brown to dark brown in color and is usually incased in a silken cocoon. (Munro and Thomson)

THE PUPAE

The pupae (fig. 4) range from light brown to dark brown in color, the variation being due to differences in age, as pupae turn darker brown as they grow older. In length they range from three-eighths to five-eighths inch, approximately, and they are usually incased in silken cocoons. The locations chosen by the larvae for pupation are not definite. In tobacco warehouses they pupate in spaces between staves of hogsheads, in the tobacco near the surface of the hogsheads, or where, in crawling about in warehouses, they find sheltered spots suitable for building cocoons.

THE ADULTS

The coloration of the adults (fig. 5) of *Ephestia elutella* is variable; some are gray, others light grayish brown. The head and thorax are brownish and the abdomen is pale gray. When the wings are folded the moths average about three-eighths inch from head to tip of wings, and the wing expanse is about one-half inch (*10*). In infested warehouses moths can be found resting on screen doors, walls, hogsheads, and boxes. Occasionally they may be seen flying during the day. Observations in tobacco warehouses revealed that moths are more active at night than during the day

and that the rapidity of flight is much greater at night. In the daytime the moths are attracted to dim lights and are most numerous in the shadows cast by rows of hogsheads.

LIFE HISTORY AND HABITS

APPARATUS AND METHOD OF STUDY

Female moths of the spring brood were collected in tobacco warehouses during the period June 22 to July 14, 1931, and records of their egg laying on flue-cured tobacco were made. The females were probably fertilized when collected; however, males were placed with them during the oviposition period. The progeny of these moths were used to secure the life-history data tabulated in this circular.

In order to obtain egg-laying records, the females were placed in individual glass vials, each containing portions of leaves of flue-cured tobacco. The vials used were 4⅛ inches long and 1 inch in diameter,

FIGURE 5.—Adult of *Ephestia elutella*, × 9 (approximately). When the wings are folded the adult measures about three-eighths inch from head to tip of wing. (Munro and Thomson)

and had close-fitting metal caps. Fresh pieces of tobacco were placed in the vials every 24 hours, and the eggs were counted with the aid of a binocular microscope. During the incubation period the daily lots of eggs, usually attached to the leaves, were left in the vials.

The larvae were reared in circular pasteboard pill boxes 1¾ inches in diameter and three-fourths inch deep. As food for the larvae, portions of flue-cured tobacco leaves and tobacco which had been ground through a 48-mesh screen were used. It was found that young larvae had difficulty in feeding on the tobacco leaves after some of the moisture had evaporated. This difficulty was overcome by using the ground tobacco in the rearing containers.

The temperatures recorded in Table 1 were obtained from the records of the United States Weather Bureau for Richmond, Va. The other temperatures recorded were obtained with a hygrothermograph located in the laboratory.

RATE OF DEVELOPMENT ON TOBACCO[3]

Table 1 contains data showing the developmental periods of 30 individuals of *Ephestia elutella* that hatched during June and July, 1931, and Table 2 contains similar data for 30 individuals that hatched during August.

TABLE 1.—*Data on development of Ephestia elutella from eggs laid on flue-cured tobacco in the laboratory at Richmond, Va., during June and July, 1931*

Rearing No.	Date egg was laid	Incubation period	Larval period	Pupal period	Date adult emerged	Sex	Period from egg to adult			
							Duration	Temperature[a]		
								Mean maximum	Mean minimum	Mean
		Days	*Days*	*Days*			*Days*	*° F.*	*° F.*	*° F.*
1	June 23	6	36	9	Aug. 13	Female	51	89.0	69.9	79.4
2	do	5	35	9	Aug. 11	Male	49	89.8	70.1	79.9
3	do	6	36	9	Aug. 13	do	51	89.0	69.9	79.4
4	do	5	41	11	Aug. 19	Female	57	89.0	69.8	79.4
5	do	5	47	13	Aug. 27	Male	65	87.4	69.0	78.2
6	do	6	42	10	Aug. 20	Female	58	79.8	69.8	74.8
7	do	7	61	9	Sept. 8	do	77	80.3	68.2	74.2
8	June 24	5	31	9	Aug. 8	do	45	89.8	70.3	80.0
9	do	5	37	11	Aug. 16	do	53	88.6	69.9	79.2
10	do	5	45	11	Aug. 24	do	61	87.5	69.4	78.4
11	do	5	44	14	Aug. 26	do	63	87.4	69.1	78.2
12	do	5	31	9	Aug. 8	Male	45	89.8	70.3	80.0
13	June 25	5	33	7	Aug. 9	Female	45	90.1	70.4	80.2
14	do	5	39	11	Aug. 19	Male	55	87.4	63.6	75.5
15	do	5	49	11	Aug. 29	Female	65	86.2	67.8	77.0
16	do	5	55	10	Sept. 3	do	70	86.2	67.6	76.9
17	do	5	47	14	Aug. 30	do	66	86.1	67.8	76.9
18	June 26	4	41	8	Aug. 18	do	53	87.5	68.0	77.7
19	June 27	5	43	14	Aug. 28	Male	62	86.3	68.1	77.2
20	June 28	5	53	9	Sept. 3	Female	67	86.2	67.8	77.0
21	July 7	3	42	12	Sept. 2	do	57	85.7	67.4	76.5
22	do	4	33	13	Aug. 26	Male	50	85.8	67.9	76.8
23	do	4	38	14	Sept. 1	do	56	85.7	67.5	76.6
24	do	4	53	9	Sept. 11	do	66	85.6	66.9	76.2
25	July 8	4	29	14	Aug. 24	do	47	85.8	68.2	77.0
26	do	4	38	15	Sept. 3	do	57	85.7	67.4	76.5
27	do	4	48	10	Sept. 8	do	62	85.4	66.4	75.9
28	July 10	4	38	13	Sept. 3	do	55	85.5	67.2	76.3
29	July 17	5	66	12	Oct. 8	Female	83	85.9	65.1	75.5
30	July 18	4	72	19	Oct. 21	Male	95	83.8	62.8	73.3
Average		4.8	43.4	11.3			59.5			

[a] The temperatures recorded in this table were obtained from the records of the United States Weather Bureau, Richmond, Va.

[3] A. W. Green, field assistant at the tobacco insect laboratory, June to September, 1931, assisted with some of the life-history studies recorded in this circular.

TABLE 2.—*Data on development of Ephestia elutella from eggs laid on flue-cured tobacco in the laboratory at Richmond, Va., during August, 1931*

Rearing No.	Date egg was laid	Incubation period	Larval period	Pupal period	Date adult emerged	Sex	Period from egg to adult			
							Duration	Temperature[1]		
								Mean maximum	Mean minimum	Mean
		Days	*Days*	*Days*			*Days*	*° F.*	*° F.*	*° F.*
1	Aug. 9	4	47	13	Oct. 12	Male	64	81.1	71.9	76.5
2	do	4	53	18	Oct. 23	Female	75	80.8	69.1	74.9
3	do	4	53	18	do	do	75	80.8	69.1	74.9
4	Aug. 11	6	35	15	Oct. 6	Male	56	80.8	72.3	76.5
5	do	6	41	15	Oct. 12	Female	62	80.8	71.7	76.2
6	do	6	40	20	Oct. 16	Male	66	80.6	70.8	75.7
7	do	6	44	16	do	do	66	80.6	70.8	75.7
8	do	6	43	17	do	do	66	80.6	70.8	75.7
9	do	6	46	15	Oct. 17	Female	67	80.6	70.6	75.6
10	do	6	46	15	do	do	67	80.6	70.6	75.6
11	do	6	44	17	do	Male	67	80.6	70.6	75.6
12	do	6	47	17	Oct. 20	Female	70	80.5	69.6	75.0
13	do	6	47	17	do	do	70	80.5	69.6	75.0
14	do	6	47	18	Oct. 21	Male	71	80.6	69.4	75.0
15	do	6	48	17	do	do	71	80.6	69.4	75.0
16	Aug. 13	5	38	13	Oct. 8	Female	56	81.2	72.9	77.0
17	do	5	38	13	do	Male	56	81.2	72.9	77.0
18	do	5	41	16	Oct. 14	Female	62	80.7	71.1	75.9
19	do	5	44	16	Oct. 17	Male	65	80.7	70.6	75.6
20	do	5	46	14	do	Female	65	80.7	70.6	75.6
21	do	5	45	16	Oct. 18	do	66	80.6	70.3	75.4
22	do	5	46	18	Oct. 21	do	69	80.7	69.4	75.0
23	do	5	48	18	Oct. 23	Male	71	80.7	68.9	74.8
24	do	5	54	12	do	Female	71	80.7	68.9	74.8
25	do	5	48	18	do	do	71	80.7	68.9	74.8
26	Aug. 14	6	43	18	Oct. 20	Male	67	80.7	69.6	75.1
27	Aug. 16	5	44	18	Oct. 22	do	67	80.8	68.9	74.8
28	do	4	53	24	Nov. 5	do	81	80.3	66.3	73.3
29	Aug. 17	6	43	17	Oct. 22	Female	66	80.7	68.8	74.7
30	do	5	51	24	Nov. 5	do	80	80.0	66.2	73.1
Average		5.3	45.4	16.7			67.5			

[1] The temperatures recorded in this table were obtained from hygrothermograph records in the laboratory, Richmond, Va.

TABLE 3.—*Data on the life history of 30 mated pairs of Ephestia elutella on flue-cured tobacco in the laboratory at Richmond, Va., 1931*

Mating No.	Date of emergence		Pre-oviposition period	Oviposition period	Post-oviposition period	Longevity		Total eggs laid	Per centage of hatch	Incubation period of eggs			Mean average daily temperature during life of female [2]
	Male	Female				Male	Female			Maximum	Minimum	Average [1]	
			Days	*Days*	*Days*	*Days*	*Days*	*Number*	*Per cent*	*Days*	*Days*	*Days*	*° F.*
1	July 28	July 28	0	10	1	9	11	183	75.4	5	4	4.1	84.5
2	July 31	July 31	0	4	1	4	5	126	81.7	6	4	4.1	84.2
3	do	do	0	4	1	3	5	108	94.4	7	4	4.3	84.2
4	Aug. 2	Aug. 2	0	5	2	7	7	104	86.5	7	5	5.3	83.5
5	do	do	0	7	3	6	10	117	17.1	7	5	6.0	82.4
6	Aug. 4	Aug. 4	1	4	1	7	6	76	92.1	6	3	4.1	83.3
7	Aug. 5	Aug. 5	1	10	2	13	13	211	78.1	7	4	4.5	79.6
8	Aug. 6	Aug. 6	1	4	2	9	7	148	93.2	7	4	4.3	80.2
9	Aug. 7	Aug. 7	1	7	2	12	10	138	65.9	7	5	5.1	79.1
10	Aug. 8	Aug. 8	1	3	6	10	10	95	35.8	8	5	6.0	78.8
11	Aug. 7	do	1	4	1	8	6	144	79.9	9	5	5.3	78.3
12	Aug. 9	Aug. 9	1	3	2	10	6	134	63.4	7	5	5.4	77.1
13	Aug. 10	Aug. 10	0	8	1	8	9	120	64.2	8	4	5.1	77.5
14	Aug. 11	Aug. 11	1	4	1	10	6	101	41.6	6	4	5.3	76.1
15	Aug. 12	Aug. 12	3	3	0	5	6	37	78.4	9	4	4.7	77.5
16	do	do	2	8	2	7	12	113	79.6	8	4	4.5	75.1
17	Aug. 13	Aug. 13	2	7	0	11	9	103	68.9	9	4	4.7	77.1
18	Aug. 14	Aug. 14	2	5	0	10	7	144	56.2	9	5	6.2	78.7
19	do	do	0	7	3	8	10	123	47.1	7	4	4.6	75.5
20	Aug. 16	Aug. 16	1	7	2	8	10	84	1.2	6	6	6.0	75.0
21	Aug. 19	Aug. 19	0	6	2	10	8	83	63.8	8	5	6.1	73.5
22	do	do	1	8	3	8	12	93	24.7	7	5	5.2	74.6
23	Aug. 20	Aug. 20	0	7	2	10	9	126	35.7	8	5	6.5	73.4
24	Aug. 21	Aug. 21	1	7	0	12	8	99	71.7	7	4	5.6	73.3
25	Aug. 24	Aug. 24	1	12	0	14	13	279	67.2	7	4	5.1	77.3
26	do	do	0	7	3	10	10	109	44.9	7	5	5.2	77.3
27	Aug. 29	Aug. 29	0	4	3	6	7	98	43.9	7	5	5.5	77.7
28	Aug. 30	Aug. 30	1	9	1	12	11	227	43.6	7	5	5.0	77.0
29	Sept. 4	Sept. 4	0	7	1	8	8	87	23.0	6	5	5.3	77.5
30	Sept. 5	Sept. 5	0	9	2	11	11	210	16.2	5	5	5.0	79.1
Average			0.7	6.3	1.7	8.9	8.7	127.3	57.8	7.1	4.5		

[1] The average of the incubation records of all eggs laid by one female.
[2] The temperatures recorded in this table were obtained from hygrothermograph records in the laboratory at Richmond, Va.

INCUBATION PERIOD

The records of development of 30 eggs laid in June and July, 1931 (Table 1), gave the following incubation periods: Maximum, 7 days; minimum, 3 days; average, 4.8 days. For the eggs laid in August, 1931 (Table 2), the incubation periods were as follows: Maximum, 6 days; minimum, 4 days; average, 5.3 days. The length of the hatching period is greatly influenced by temperature. For example, the maximum period of 7 days (Table 1) occurred during the period June 23 to 30, when the mean average temperature was 75.1° F.; whereas the minimum period of 3 days (Table 1) occurred during the period July 7 to 10, when the mean average temperature was 81°. The longest incubation period observed in the laboratory was 17 days, in November, 1931, when the mean average temperature was about 55.9°.

As shown in Table 3, the incubation periods of all hatched eggs ranged from 3 to 9 days, the average being 4.5 to 7.1 days. Observations were made on all of the 3,820 eggs laid by 30 females.

LARVAL PERIOD

The developmental periods of larvae reared on flue-cured tobacco are given in Tables 1 and 2. The periods shown in Table 1 ranged from 29 to 72 days. These larvae showed an uneven rate of growth despite the fact that they were all provided with the same quality of tobacco and handled in a similar manner. Temperature is undoubtedly a very vital factor in the growth of the larvae, although some individuals developed very slowly during hot summer weather. Larva No. 25 (Table 1) required 29 days to complete its growth, at a mean temperature of 81.2° F.; whereas larva No. 30 required 72 days, at a mean temperature of 75.3°. Owing to this uneven rate of growth, it is difficult to draw conclusions as to the effects of temperature. The larval periods of the individuals shown in Table 2 ranged from 35 to 54 days. Here again the rate of growth was uneven. For example, larva No. 4 (Table 2) required 35 days for the larval period, and larva No. 15 required 48 days. These larvae hatched on August 17 and were exposed to similar conditions in the laboratory.

PUPAL PERIOD

The pupal periods shown in Table 1 occurred during August and September, when summer temperatures prevailed, the average period being 11.3 days. The shortest period was 7 days, at a mean temperature of 81.6° F. and the longest 19 days, at a mean temperature of 63.3°. The periods shown in Table 2 ranged from 12 days, at a mean temperature of 58.2°, to 24 days, at a mean temperature of 57°. The pupal periods shown in Table 2 occurred during October and November, the average for the 30 pupae being 16.7 days. Most of the larvae pupated in loosely woven cocoons near the surface of the tobacco in which they were reared.

EGG-TO-ADULT PERIOD

There is a wide variation between the shortest and the longest egg-to-adult period, as shown in Tables 1 and 2. In Table 1 rearings Nos. 8, 12, and 13 completed the cycle in 45 days, at mean temperatures of 80°, 80°, and 80.2° F., respectively. Rearing No. 30 required 95 days to complete the cycle, at a mean temperature of 73.3°.

In Table 2 rearings Nos. 4, 16, and 17 completed growth in 56 days, when the mean temperatures were 76.5°, 77°, and 77° F., respectively. The longest period in Table 2 (that required in rearing No. 28) was 81 days, at a mean temperature of 73.3°. The length of the egg-to-adult period is influenced by temperature. During hot weather most individuals have a more rapid growth. It was observed, however, that there are larvae upon which temperature appears to have little effect. As an illustration, rearing No. 30 (shown in Table 1) hatched July 22 but did not complete its cycle until October 21.

DATA ON MATED MOTHS

During July, August, and September, 1931, females of *Ephestia elutella* were mated on the day they emerged. Data concerning these moths are given in Table 3. All the females listed in Table 3 were mated on the date of their emergence. Each pair of moths was segregated in a glass vial and given a small piece of flue-cured tobacco leaf. The tobacco was replaced by a fresh piece every 24 hours, and the eggs laid during this interval were counted. It was observed that

females preferred to oviposit on tobacco rather than on the glass vial, practically all the eggs laid being attached to the tobacco leaf.

The daily lots of eggs were left on the tobacco leaf and examined every 24 hours for hatching. The hatched larvae were separated each day from the unhatched eggs and the number recorded. This procedure was followed in handling all daily lots of eggs to obtain incubation records. The unhatched eggs of each lot were examined for 10 days after the last hatch was recorded. By this time all unhatched eggs had become dried, shrunken, and distorted in shape, and it was apparent that further observations were unnecessary.

The percentages of hatch for all eggs recorded in Table 3 ranged from 94.4 per cent to as low as 1.2 per cent, the average for the 3,820 eggs being 57.8 per cent. The average of all the incubation periods (Table 3) was: Average maximum, 7.1 days; average minimum, 4.5 days. The mean average daily temperature during the period of longevity was calculated for each female and ranged from 73.3° to 84.5° F.

The preoviposition periods ranged from less than a day to 3 days, the average being 0.7 day. The oviposition period ranged from 3 to 12 days, averaging 6.3 days; and the postoviposition period ranged from less than a day to 6 days, averaging 1.7 days.

The longevity of female moths ranged from 5 to 13 days, the average being 8.7 days. In most instances high temperature reduces the length of life of females. However, there are exceptions, as shown in Table 3. For example, females Nos. 2 and 3 each lived for 5 days at a mean temperature of 84.2° F., while female No. 1 lived 11 days at a mean temperature of 84.5°. Laboratory records show that six females that emerged and mated in November had an average longevity of 14.6 days when the mean temperature was 59.2°.

The total number of eggs laid ranged from 279 (laid by female No. 25) to 37 (laid by female No. 15), the average being 127.3. Owing to the variation in the number of eggs laid, no conclusions regarding the effects of temperature on egg laying can be drawn from these data.

EGG LAYING

The small grayish-white eggs of *Ephestia elutella* were ordinarily laid on the tobacco leaves. The eggs, when laid, are covered with a gluey coating, which usually attaches them to the leaves. The number of eggs laid during 24 hours was variable. The daily egg-laying records of the females listed in Table 3 are presented in Table 4. As shown in this table, the number of eggs laid during 24-hour periods by one female ranged from 0 to 90. Female No. 11 laid 90 eggs on August 10, when the temperature ranged from 91° to 78° F. More eggs were laid the second day after emergence than on any other day and most of the egg laying took place during the first five days of the life of each female.

TABLE 4.—*Record of deposition of eggs on flue-cured tobacco in the laboratory by 30 females of Ephestia elutella at Richmond, Va., 1931*

Female No.	Date female emerged	Eggs laid days after emergence [1]													Total number of eggs laid
		1	2	3	4	5	6	7	8	9	10	11	12	13	
1	July 28	6	61	27	10	5	23	16	12	15	8	0			183
2	July 31	81	28	13	4	0									126
3	do	2	62	32	12	0									108
4	Aug. 2	62	25	10	4	3	0	0							104
5	do	8	43	8	6	37	9	6	0	0	0				117
6	Aug. 4	0	22	25	21	8	0								76
7	Aug. 5	0	81	43	20	4	2	20	14	14	7	6	0	0	211
8	Aug. 6	0	77	42	18	11	0	0							148
9	Aug. 7	0	36	59	27	13	0	2	1	0	0				138
10	Aug. 8	0	49	35	11	0	0	0	0	0	0				95
11	do	0	90	46	7	1	0								144
12	Aug. 9	0	71	42	21	0	0								134
13	Aug. 10	1	14	51	24	16	6	7	1	0					120
14	Aug. 11	0	52	21	20	8	0								101
15	Aug. 12	0	0	0	25	11	1								37
16	do	0	0	4	63	19	14	6	0	6	1	0	0		113
17	Aug. 13	0	0	53	24	9	8	6	1	2					103
18	Aug. 14	0	0	18	76	29	12	9							144
19	do	14	52	32	15	3	5	2	0	0	0				123
20	Aug. 16	0	1	48	21	13	0	0	1	0	0				84
21	Aug. 19	4	57	18	0	3	1	0	0						83
22	do	0	38	1	5	21	13	5	4	6					93
23	Aug. 20	51	17	14	23	11	6	4	0	0					126
24	Aug. 21	0	48	11	18	7	11	0	4						99
25	Aug. 24	0	80	51	42	41	20	14	2	13	9	2	4	1	279
26	do	11	47	37	9	2	2	1	0	0	0				109
27	Aug. 29	11	51	31	5	0	0	0							98
28	Aug. 30	0	37	64	39	16	7	21	14	17	12	0			227
29	Sept. 4	1	40	13	25	5	0	3	0						87
30	Sept. 5	31	45	30	28	17	22	25	8	4	0	0			210
Total		283	1,224	879	623	313	162	147	62	77	37	8	4	1	3,820

[1] The egg-laying records extend from the day of emergence to the day of death of the female.

DISCUSSION

SEX RATIOS

The egg-to-adult rearings shown in Tables 1 and 2 were composed of 60 moths, 46.7 per cent males and 53.3 per cent females. The sex of 473 additional moths collected in infested tobacco warehouses was determined; of these, 60 per cent were males and 40 per cent females.

NATURAL ENEMIES FOUND ATTACKING EPHESTIA ELUTELLA

During the summer of 1930 a wasplike insect was observed parasitizing the larvae of *Ephestia elutella*. Specimens were identified by A. B. Gahan, of the Bureau of Entomology, as *Microbracon hebetor* (Say). During October and November, 30 egg-to-adult rearings of this parasite were completed in the laboratory, well-grown larvae of *E. elutella* being used as food. The developmental periods were as follows: Incubation period, 2 to 3 days; larval period, 8 to 10 days; pupal period, 9 to 12 days; and egg-to-adult period, 20 to 24 days. These records were obtained when the temperature ranged from 73° to 78° F. The effectiveness of this parasite in reducing the numbers of *E. elutella* larvae in tobacco warehouses has not been determined.

A small mite was collected in tobacco warehouses during the summer of 1930 from the bodies of adults of *E. elutella*. Specimens were identified by H. E. Ewing, of the Bureau of Entomology, as a species of Seius.

FIGURE 6.—Individual tobacco leaves illustrating the work of larvae of the cigarette beetle (*Lasioderma serricorne*) in cured tobacco

THE WORK OF LARVAE IN TOBACCO

As the work of the larvae of the cigarette beetle (*Lasioderma serricorne*) is well known to the tobacco trade, the feeding of the larvae of *Ephestia elutella* will be contrasted with that of larvae of the cigarette beetle. The feeding of larvae of *E. elutella* is illustrated in Figure 1 and that of cigarette-beetle larvae in Figure 6.

Full-grown larvae or grubs of the cigarette beetle (fig. 7) are about one-sixth inch long. They are yellowish in color and are usually found lying in a curved position in their feeding tunnels. The bodies are covered with brownish hairs, to which finely pulverized particles of tobacco adhere. They tunnel through tobacco leaves in infested hogsheads and cases, leaving holes that vary in size according to the age of the larvae.

The full-grown larvae of *Ephestia elutella* (fig. 2) are from three-eighths to five-eighths inch long They are cylindrical, slightly tapering toward the head, and usually of a brownish color when feeding on tobacco. They have brown spots on the dorsal side of the body, which give them a striated appearance, and the bodies are sparsely covered with colorless hairs.

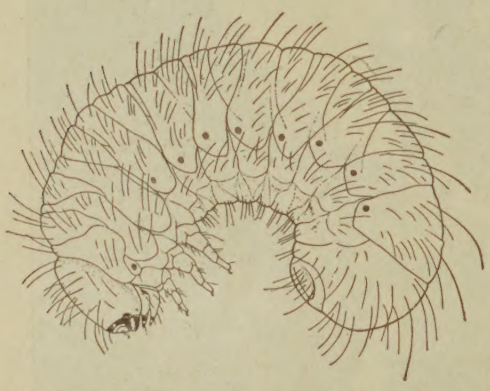

FIGURE 7.—Larva, or grub, of the cigarette beetle (*Lasioderma serricorne*). A full-grown larva is about one-sixth inch long when straightened out. (Back and Cotton)

Larvae of *E. elutella* usually feed from the stem end of tobacco leaves toward the tip. Figure 1 shows that a large portion of the leaf surface is consumed by these larvae. They feed between the midribs and larger veins of the leaves and pollute the uneaten parts with webbing to which particles of their excrement adhere. This webbing, with the attached black pellets of excrement, is objectionable to buyers or manufacturers. Larvae have been found feeding as deep as 8 inches from the staves of tobacco hogsheads, and have demonstrated their capacity to damage stored leaf tobacco seriously.

Larvae of the cigarette beetle eat or burrow irregularly shaped tunnels in the leaves. (Fig. 6.) Often these tunnels are filled with tobacco dust and excrement of the larvae, which soils tobacco when the infestations are heavy.

THE PROBLEM OF CONTROL

Tobacco is usually held in storage from one to three years for aging before it is manufactured, and bright tobacco is sometimes held four years or longer. It is therefore necessary for dealers and manufacturers to carry on hand from year to year large stocks of tobaccos. Such long storage periods enable *Ephestia elutella*, under favorable conditions, to build up large populations and inflict serious injury. Examinations of infested hogsheads indicate that the pollution from the webbing and excrement of the larvae often occasions greater losses than the actual devouring of the leaf. The tobacco trade should make a determined effort to locate warehouse infestations of this insect and prevent their spread.

Tobacco infested by the moth should be promptly fumigated. The writers are conducting experiments in tobacco warehouses with the available fumigants to determine the conditions necessary for the control of this moth in hogsheads and cases of tobacco. The infested tobacco warehouses have been fumigated with hydrocyanic acid gas, which has greatly reduced the number of insects. Further fumigation experiments for the control of this new tobacco pest will be conducted by the Bureau of Entomology.

The tobacco trade can assist in preventing the spread of *Ephestia elutella* by reporting new infestations promptly and by arranging for fumigations to be conducted by experienced persons.

SUMMARY

Ephestia elutella Hbn. has appeared in the bright-tobacco belt of the United States as a pest of flue-cured tobacco. It has also been recorded as a pest of tobacco in Russia, England, Southern Rhodesia, Poland, Bulgaria, and Greece.

Female moths were collected from tobacco warehouses on June 22, 1931. The progeny of these moths were used in life-history studies in the laboratory at Richmond, Va., during the summer and fall of 1931.

The duration of the egg-to-adult period of individuals that hatched in June and July ranged from 45 to 95 days, whereas those that hatched in August required 56 to 81 days to complete the cycle. This uneven rate of development makes it difficult to judge the effects of temperature on the insect.

Data on 30 mated pairs are presented, including daily records of egg laying. The average longevity of the females was 8.7 days, the mean average temperatures ranging from 73.3° to 84.5° F. The average lengths of the different periods were as follows: Preoviposition period, 0.7 day; oviposition period, 6.3 days; postoviposition period, 1.7 days.

The total number of eggs laid by one female ranged from 37 to 279, the average being 127.3. Records of incubation of 3,820 eggs are given, showing the following variations: Average maximum, 7.1 days; average minimum, 4.5 days. The total number of eggs laid by one female during 24 hours ranged from 0 to 90. Most of the egg laying took place during the first five days of each female's life.

Larvae usually feed from the stem end of the tobacco leaf toward the tip. They have been found feeding as deep as 8 inches from the staves in hogsheads of tobacco and have demonstrated their capacity to inflict serious damage on leaf tobacco.

From the data presented it is probable that four generations develop from June 1 to October 31 in unheated warehouses in the bright-tobacco belt.

Moths reared in the laboratory showed a ratio of 46.7 per cent males to 53.3 per cent females, and those collected from infested warehouses a ratio of 60 per cent males to 40 per cent females.

Microbracon hebetor (Say) was collected while it was parasitizing the larvae of *Ephestia elutella*, and a small mite, *Seius* sp., was found attacking adults.

The work of larvae of *E. elutella* is contrasted with that of the cigarette-beetle larvae, as an aid to tobacco dealers and manufacturers in identifying infestations.

Stored tobacco infested by *E. elutella* should be fumigated promptly. The tobacco trade may assist in preventing the further spread of this insect by arranging for fumigations. These, to be effective, should be conducted by experienced persons.

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